# THE INTEGRATION OF AERIAL AND CLOSE-RANGE PHOTOGRAMMETRY FOR LEVELS OF DETAILS REPRESENTATION IN CITY MODELING

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# THE INTEGRATION OF AERIAL AND CLOSE-RANGE PHOTOGRAMMETRY FOR LEVELS OF DETAILS REPRESENTATION IN CITY MODELING

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# Special Dedication

This thesis are dedicated

to

Fiancee

Mohd Hilmi bin Abdullah

Ayah

Amat bin Maswan

Mak

Nor'Aini bt Awang

Abang

Mohd Idzuan

Adik

Nor Anizah

*Thanks for your loves, understand and continuous support*

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## ABSTRACT

Aerial photogrammetry data is commonly used to develop three-dimensional (3D) city model. There are some problems in constructing 3D city model by using aerial photogrammetry including the difficulties in recognition of small buildings and levels of details of building geometry is limited. Besides that, newly constructed buildings are not recorded in the aerial image. In order to improve aerial photogrammetry data for 3D city model development, this research was conducted by integrating aerial photogrammetry data with close-range photogrammetry data. This study also verifies the levels of details of buildings achieved by close-range photogrammetry. The base model and building model are the main components of 3D city model. The base model was developed from aerial photogrammetry data and consists of Digital Terrain Model. The building models were generated from aerial and close-range photogrammetry data. Aerial photogrammetry was used to generate the whole buildings in the study area, while close-range photogrammetry was used to develop the small building that is difficult to recognize and new building that is not recorded in aerial image. The buildings from aerial and close-range photogrammetry were integrated with the base model to form 3D city model. At the end of this study, the 3D city model was presented in 3D visualization. The building models from close-range photogrammetry were evaluated in terms of levels of details, geometry and accuracy. In conclusion, the building models from close-range photogrammetry have achieved levels of details of level three where building geometry consists of architectural elements such as windows and doors. The accuracy of the building models from close-range photogrammetry is less than one centimeter when compared with measurement from total station Leica TCR 307. Furthermore, the integration of aerial and close-range photogrammetry have contributed in terms of updating the building models in 3D city model data.

# ABSTRAK

Data fotogrametri udara sering digunakan untuk membangunkan model tiga dimensi (3D) bandar. Terdapat beberapa masalah dalam membina model 3D bandar dengan menggunakan fotogrametri udara termasuklah kesukaran dalam mengenalpasti bangunan kecil dan tahap butiran bagi geometri bangunan adalah terhad. Di samping itu, bangunan yang baru dibina tidak direkodkan di dalam imej udara. Dalam usaha untuk menambahbaik data fotogrametri udara untuk pembangunan model 3D bandar, kajian ini dijalankan dengan mengintegrasikan data fotogrametri udara dengan data fotogrametri jarak dekat. Kajian ini juga menentukan tahap butiran bangunan yang dicapai oleh fotogrametri jarak dekat. Model dasar dan model bangunan merupakan komponen utama model 3D bandar. Model dasar dibangunkan daripada data fotogrametri udara dan ianya terdiri daripada Model Permukaan Digital. Model bangunan pula dibangunkan dari data fotogrametri udara dan jarak dekat. Fotogrametri udara telah digunakan untuk menghasilkan keseluruhan bangunan di kawasan kajian, manakala fotogrametri jarak dekat telah digunakan untuk membangunkan bangunan kecil yang sukar untuk dikenalpasti dan bangunan baru yang tidak direkod dalam imej udara. Bangunan-bangunan dari fotogrametri udara dan jarak dekat diintegrasikan dengan model dasar untuk membentuk model 3D bandar. Pada akhir kajian ini, model 3D bandar dibentangkan dalam visualisasi 3D. Model-model bangunan daripada fotogrametri jarak dekat dinilai dari segi tahap butiran, geometri dan ketepatan. Sebagai kesimpulan, model-model bangunan daripada fotogrametri jarak dekat telah mencapai tahap butiran tahap yang ketiga dimana geometri bangunan terdiri daripada unsur-unsur seni bina seperti tingkap dan pintu. Ketepatan model bangunan daripada fotogrametri jarak dekat adalah kurang daripada satu sentimeter apabila dibandingkan dengan pengukuran dari alat *total station Leica TCR 307*. Di samping itu, integrasi fotogrametri udara dan jarak dekat telah menyumbang dari segi mengemaskini model-model bangunan dalam data model 3D bandar.

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| | |
|---|---|
| CAD | Computer Aided Design |
| CRP | Close-Range Photogrammetry |
| DEM | Digital Elevation Model |
| DVP | Digital Video Plotter |
| DXF | Drawing Exchange Format |
| DTM | Digital Terrain Model |
| KML | Keyhole Markup Language |
| LoD | Levels of Details |
| LIDAR | Light Detection and Ranging |
| GIS | Geographic Information System |
| IT | Internet Technology |
| GML | Geography Markup Languange |
| TIN | Triangular Irregular Network |
| 2D | Two-Dimensional |
| 3D | Three-Dimensional |
| 3ds | 3D Studio Max |
| Mdb | Multipatch database |
| VRML | Virtual Reality Markup Language |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background of the study

The development of three-dimensional (3D) city model has been widely used for data management, urban planning, environmental visualisation, and mapping. Generally, there are various meanings or terms to describe the 3D city model. Marcel and Dieter (2004) stated that 3D city models refer to a semantic description of objects in a city including 3D information. The 3D city model consist of fundamental component such as Digital Terrain Model (DTM), building models, street space models, and green space models (Jurgen et al., 2006). Therefore, the meaning of 3D city models can be simplified to the representation 3D graphic of city in the real world.

In developing 3D city model, it is important to choose the appropriate data and suitable method (Kobayashi, 2007 and Ziuriene, 2003). There are three methods which can be used to build the 3D city model; traditional, automatic, and semi-automatic methods. Automatic and semi-automatic methods are currently used to generate 3D city model as compared to manual method. This is because, manual method requires enormous time to manually develop 3D city model (Takase et al., 2003). Automatic method is the fastest method in developing 3D city model. However, the problem occurs to acquiring the laser profiler data such as Light Detection and Ranging (LiDAR). The cost of data acquisition is too expensive and need high performance computer to handle large amount of data. The semi-automatic method is preferred by most users in developing 3D city model. This is because, the semi-automatic method uses photogrammetry approach such as aerial images to develop 3D city model which save time compared to the automatic method. The data for this method is easy to acquire base on previous aerial photogrammetry survey.

The demands for 3D city models in mapping, planning and navigation has recently raised great attention from worldwide Geographic Information System (GIS) users, environmental agencies, survey department, researchers and private companies. In Germany, the application of 3D city model has been expanded to real-time visualisation. The 3D city of Stuttgart, Germany was developed to visualise the 3D Urban Landscape in real-time by using open source software (Kada et al., 2003). The real-time visualisation of 3D city model has becoming more useful and interactive because the 3D has the capabilities to walking or flying through the model.

In addition, the growing numbers of mobile navigation subscribers attract researchers and private companies in extending their mobile navigation two-dimensional (2D) map into 3D map thus improving the 3D visualization to the realistic visualization. Mobile Navigation with 3D city models (MONA3D) is one of the examples for the application of 3D city model in mobile device (Coors and Zipf, 2007).

Nowadays, the need of 3D city model has raised great attention from local government to manage and visualise their country. The importance of 3D city model has raised attention from Senate Departments of Economics and Urban Development of Berlin to manage the urban development. In 2003, Senate Departments of Economics and Urban Development of Berlin has established the requirement to identify the city model system for integrating, managing, presenting, and distributing complex urban geoinformation (Jurgen et al., 2006). Figure 1.1 shows the 3D city model of Berlin developed for tourism, entertainment, and public participation.

**Figure 1.1** Berlin 3D City Models (Jurgen et al., 2006)

Since Malaysia experiencing the advancement in Information Technology, Malaysia should develop the 3D city model for mapping, urban planning and management. Furthermore, the implementation of 3D city model for research purposes should be extended. Small steps been taken in order to develop the Virtual Cities of Malaysia by signing memorandum of understanding (MoU) between Malaysia and Safa Rayaneh which is the Iranian multi-national company (Shamsiah, 2007). However, the mission are not well established because the Safa Rayaneh 3D city model is only targeting to market their software in Malaysia without providing a well established method and procedure to develop the 3D city model. Therefore, further research on 3D city model should discover in order to find a well-established method and procedure to develop the 3D city model.

## 1.2 Problem Statement

Aerial photogrammetry is a low cost method in 3D city model development compare to LIDAR and mostly used in developing the 3D city model. In the earlier production of 3D city model by using aerial photogrammetry, Vermeij and Zlatanova (2001) had reconstructed the building model as a block model. The block model is extracted by digitizing the building shape from the roof view on the aerial images. Textures and roof is not visualised in the block model and this is categorised into Levels of Details one (LoD1) in 3D city model development. Flamanc etal., (2003), improved the 3D building model by adding roof on top of the block model without textures. Then it followed by Kobayashi (2007), who improved the building model textures and geometry.

However, there is still some constraint in developing building model from aerial images such as the recognition of the small building in aerial images. The problems are due to the resolution of aerial images and the obstacle prevents from getting the information of building. In addition, the information of new constructed building does not exist in aerial images. To acquire the new aerial images is too expensive due to the cost for flight operation.

At present, the interest of LoD of buildings became the main topic in 3D city model development. The high LoD represent the details façade and geometry of the buildings. The facade and geometry of the building from aerial images is visible from the air. The architectural instalments such as windows, door or balconies are not visible in aerial images. In order to achieve the high LoD, the aerial data could not provide the high LoD. An external data is required to combine with aerial data.

The external data from the ground might be suitable data that can be used to develop high LoD of building in 3D city model development. The data from total station, terrestrial laser scanning, and close-range photogrammetry (CRP) are possible to use as external data. This study used CRP as an external data to develop the 3D city model. The objectives of the study related to the 3D city model development are explained in Section 1.3.

## 1.3 Objectives

The objectives of this study are:-

i. To develop the simulation of 3D city model using photogrammetry approach by integrating aerial and close-range photogrammetry (CRP).

ii. To verify the LoD of buildings achieved by CRP in 3D city model development and to evaluate the quality of 3D model from the CRP in terms of the geometry and textures.

## 1.4 Scope of the Study

The scope of this study is given below:

i. To develop the simulation of 3D city model by combining the data from aerial photogrammetry and CRP. Research area is located at *Lingkaran Ilmu*, Universiti Teknologi Malaysia (UTM), Skudai. The UTM area is selected as a simulation of a city even though it is not a city.

ii. Aerial photogrammetry is used to extract the 3D information for the development of base model and building model. The data acquisition of aerial photogrammetry is not part of this study but the data are taken from the existing data provided by the *Jabatan Ukur dan Pemetaan Malaysia* (JUPEM). The procedure of aerial photogrammetry includes the process to extract 3D information which used to develop the base model. The Digital Video Plotter (DVP) software is used for aerial images processing.

iii. The CRP is used to reconstruct the 3D building which cannot be extracted from aerial images. To construct the 3D building model, CANON EOS 500D digital camera and Photomodeler 6.0 software are used.

iv. To generate the base model and integrate the base with 3D building by using the ArcScene software.

v. Two types of visualisation are created as the presentation of the 3D city model. The first visualisation is an animation of the 3D city model which present in video format. The second visualisation is created as the viewer which the 3D city model can be navigated through the viewer. The visualisation of the 3D city model is created using ArcScene and Visual Basic 6.0.

## 1.5 Significance of the Study

The development of 3D city model gives potential benefits to the urban development process especially in managing and visualising the urban changes of a city. The visualisation of the city in 3D animation is more consistent in various aspects especially in architectural, planning and management. Therefore, the development of 3D UTM Campus is the initial stage to put into practice the 3D city model environment into the Malaysian surroundings.

In addition, this study consists of several contributions:-

i. 3D photogrammetric mapping.
Currently, the photogrammetry can serve 3D data but it is used to produce the 2D map. This study uses photogrammetry to develop 3D model and the method of this study gives potential to moves forward from 2D mapping into 3D mapping.

ii. Low-cost method in the development of 3D City model.
The development of 3D city model by using photogrammetry approach is low cost method as compared to the laser scanning method in term of data acquisition and data processing.

iii. Update the 3D city model

The use of CRP in 3D city model development can be used as an alternative to updates the data in existing 3D city model especially in updating the new developed building which are not available in the existing 3D city model.

## 1.6 Research Methodology

The research methodology of this study is described in the flow chart as shown in Figure 1.2.

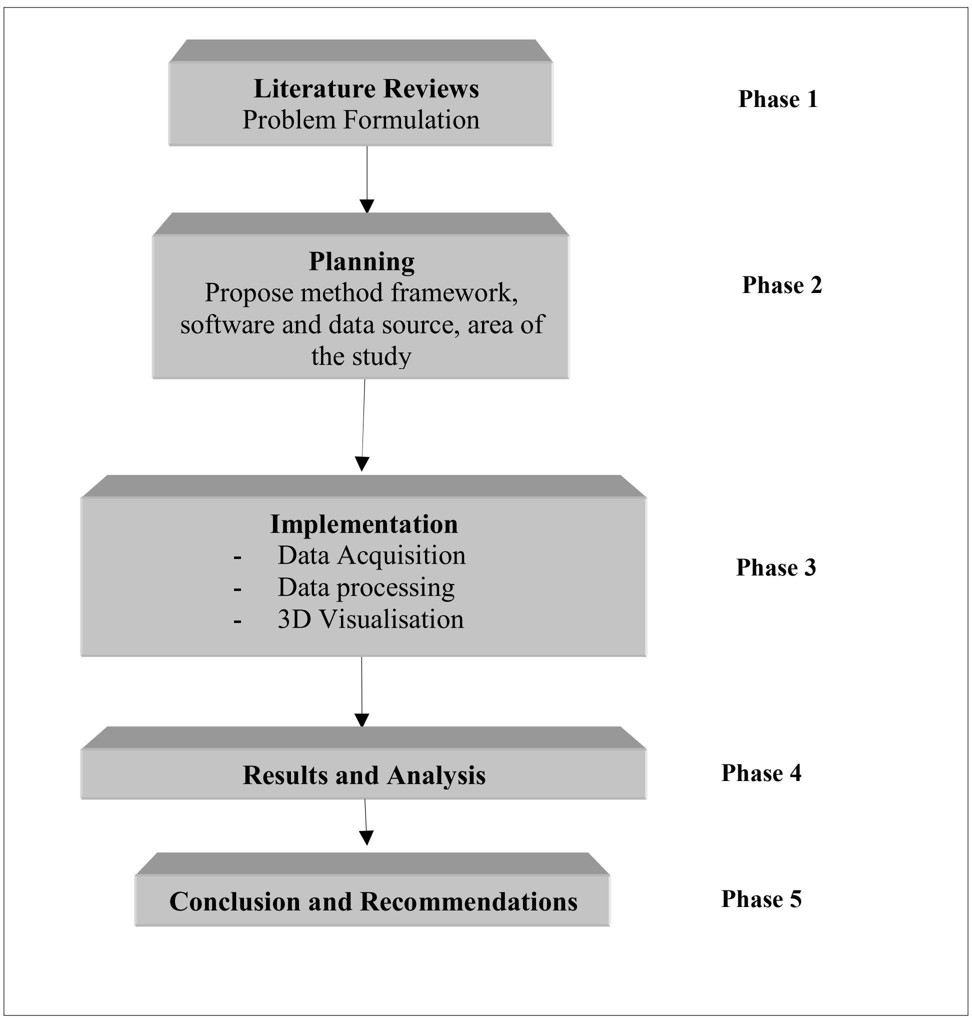


**Figure 1.2** Research methodology flow chart

Based on Figure 1.2, there are five phases of the research; literature reviews, planning, implementation, results and analysis, conclusion and recommendations.

i. Literature Review (Phase 1)

Literature reviews compiles the references based on the 3D city model that covered in term of data sources, methods and reviews on previous methods. The relevant research previously had done on this topic serves as guidelines to this research purposes.

ii. Planning (Phase 2)

The planning includes data selection, study area, data acquisition and data processing. The details of the methodology framework are discussed in Section 3.1.

iii. Implementation (Phase 3)

The implementation in this research includes data collection, data processing and 3D visualisation of 3D city model. In developing 3D city model, there are three important stages; the development of base model, building reconstruction and integration process. The first stage of this study does not involve the data collection process because the development of the base model used the existing data. The existing data is the aerial photogrammetry data. The second stage involves close-range photogrammetric data collection. The data processing starts at the beginning of the project until at the end of the project. The final product of this study is the visualization of the 3D city model.

iv. Results and Analysis (Phase 4)

The result of this study covers the presentation of the base model, 3D building model and the visualization of the 3D city model after the integration process. The analyses in this study are focuses on the visual and quality of 3D building model that have been developed. In addition, the results of 3D building model from CRP are evaluated to know the ability of CRP in developing 3D city model.

v. Conclusion and Recommendations (Phase 5)

The conclusion of this study related to the results and analysis. The recommendations are made to improve the quality in the future studies.

## 1.7 Structure of the Chapters

This research is divided into five chapters :-

i. Chapter 1 : Introduction

This chapter discussed the topic of the research such as background of the study, problem statement, objectives, scope, and significance of the study and research methodology.

ii. Chapter 2 : Reviews on 3D city model and Photogrammetry

The reviews on 3D city model and Photogrammetry are discussed in this chapter.

iii. Chapter 3 : Methodology

This chapter deals with the whole method in developing the 3D city model including data collection and data processing.

iv. Chapter 4 : Results and Analysis

The result and analysis are discussed in this chapter. Result shows the visualization of 3D city model with building model from aerial and close-range photogrammetry. Visual analysis and accuracy assessment of base model, and building model from CRP are also discussed in this chapter.

v. Chapter 5 : Conclusion

This chapter consists of conclusion of the research, problems occurred during research implementation and recommendation on future research.

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